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EP 0568376 A US 4467189 A

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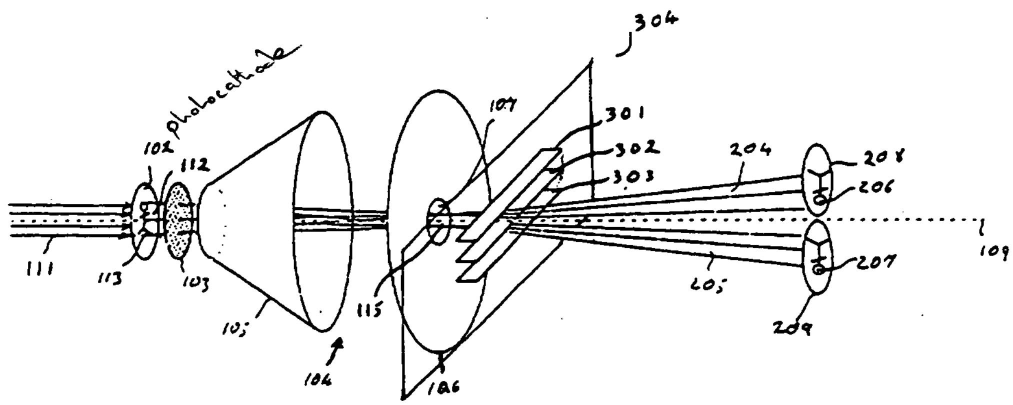
(54) Abstract Title
Image multiplier

(57) To produce a plurality of time-resolved images from an input photon image 113, e.g. an X-ray image, a single focused beam of electrons from a photocathode 102 is divided and used to produce separate images 206,207 in time-switched electron-image converter tubes, e.g. each comprising a microchannel plate and a phosphor screen. The electron beam may be divided by one or more sets of parallel electrodes 301,302,303 positioned in the neighbourhood of the near field plane 304 of the electron focusing system 104. Alternatively, the beam may be split electromagnetically.



• novelty - only

FIGURE 3

• single photocathode (ungated)

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Prior art.

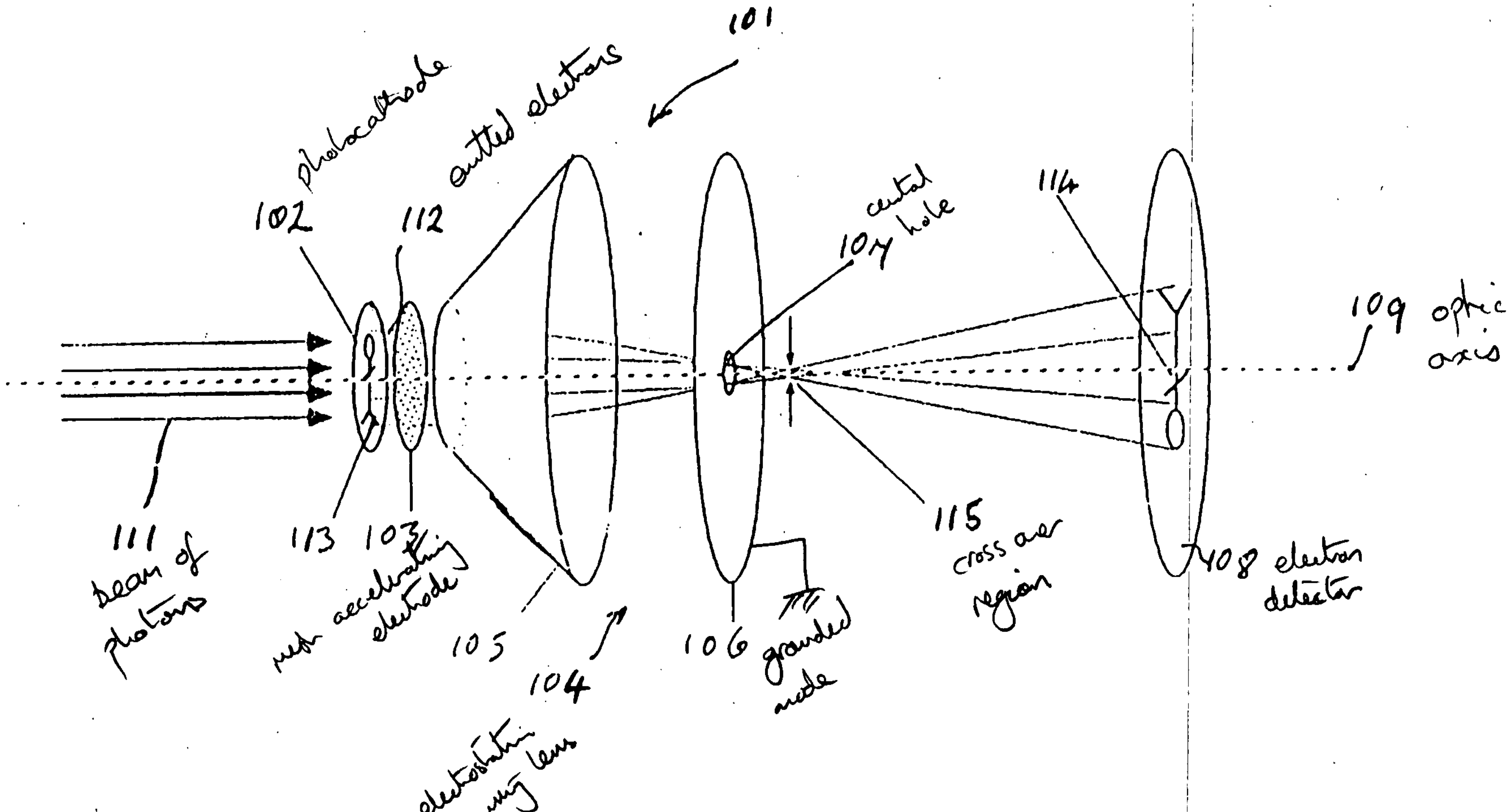


FIGURE 1

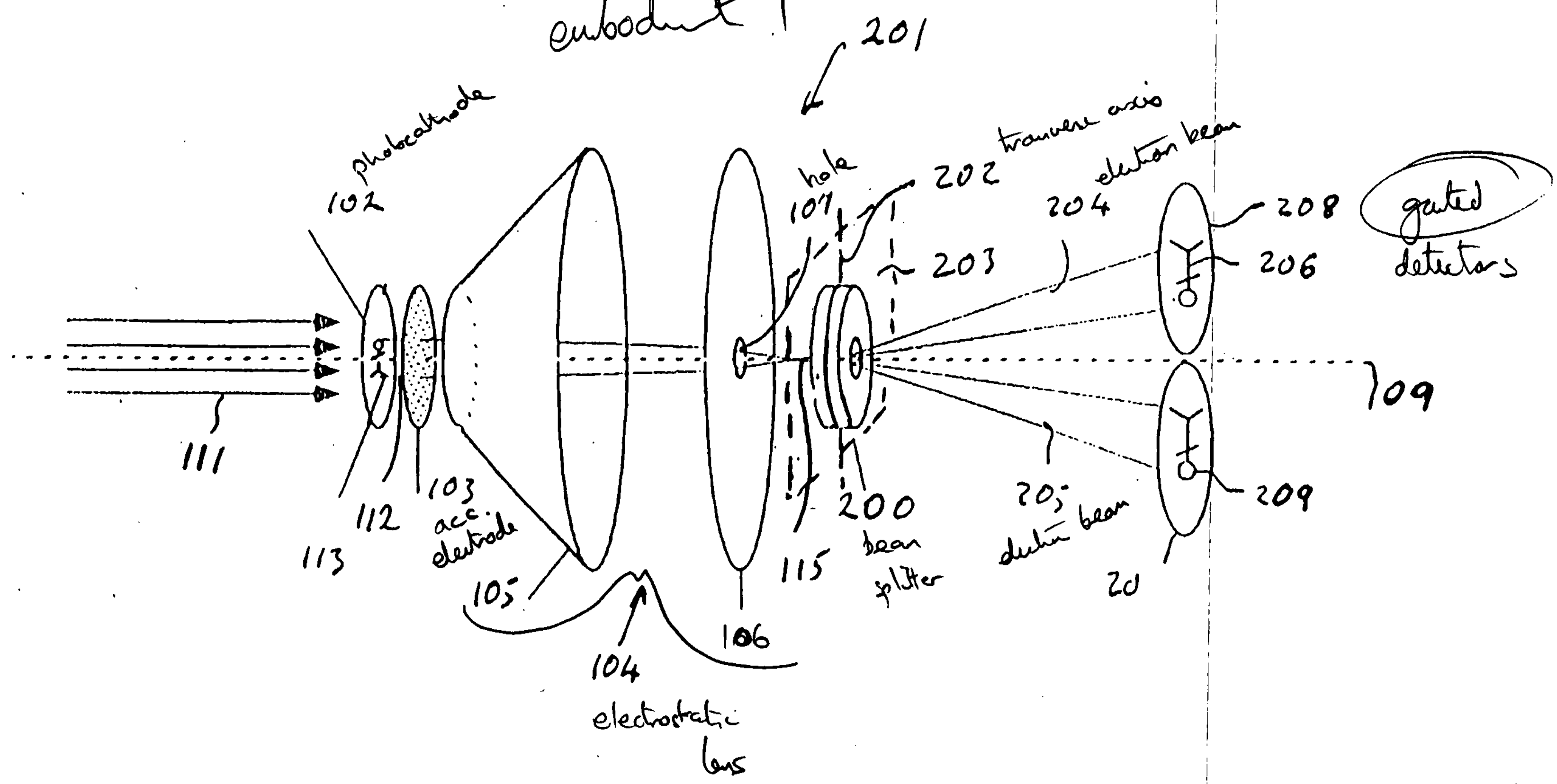
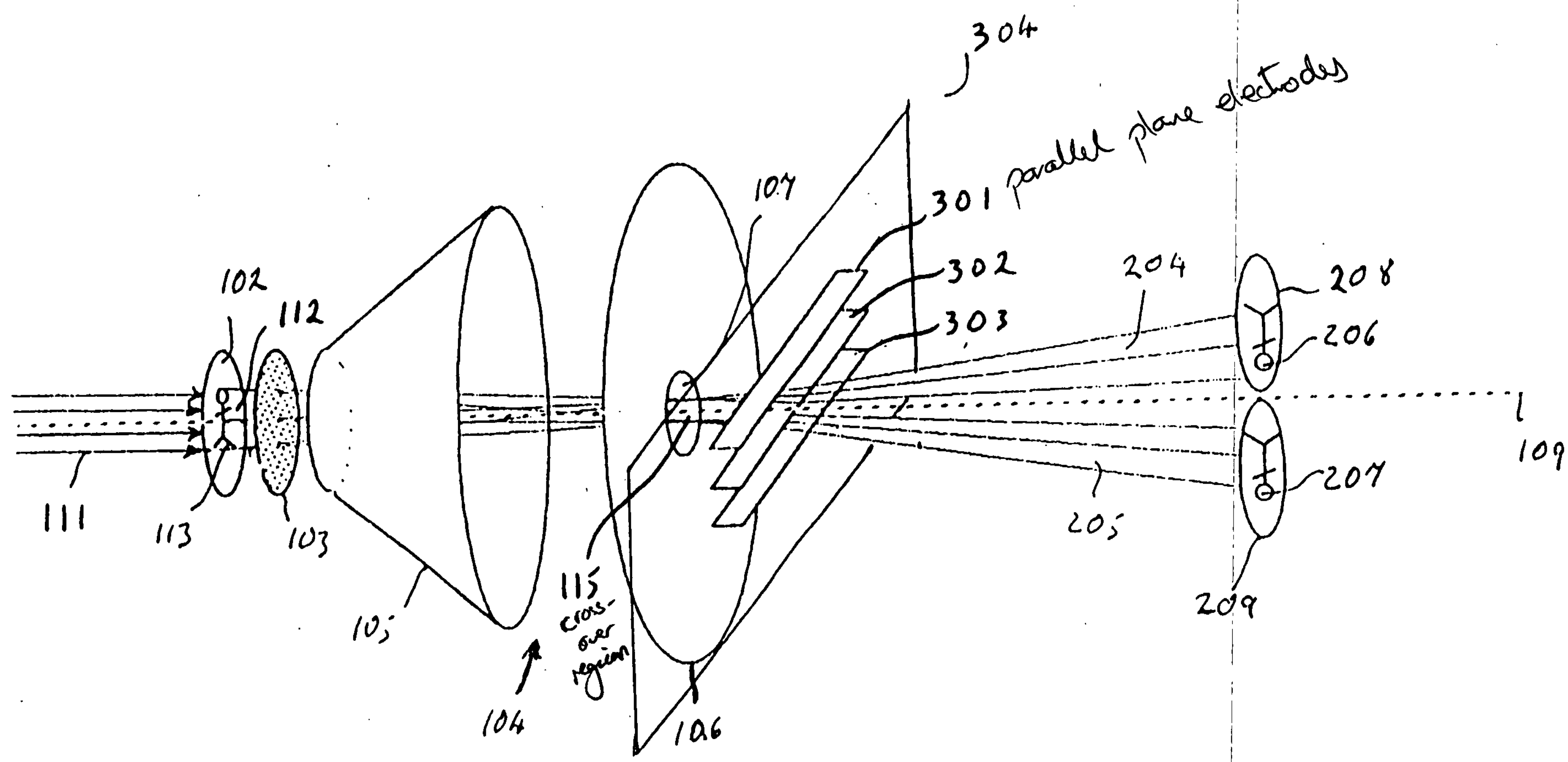

embodiment 1
201
photocathode
102
hole
107
202
transverse axis
electron beam
204
203
208
206
gated detectors
109
111
113
112
103
acc. electrode
105
104
electrostatic lens
106
115
200
beam splitter
205
electron beam
20
209

FIGURE 2



304
301 parallel plane electrodes
302
303
107
102
112
111
113
103
105
104
115 cross-over region
106
204
205
208
206
207
209
109

FIGURE 3

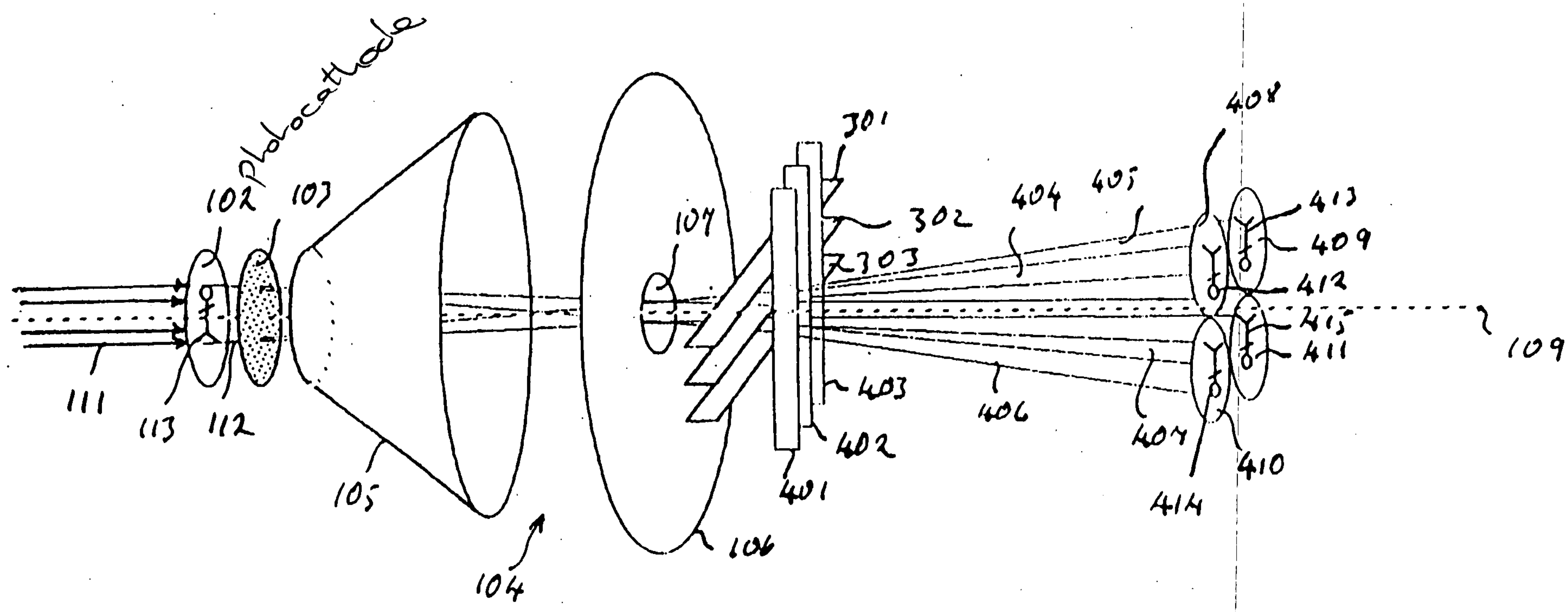

photocathode
102
103
111
113
112
105
104
107
106
301
302
303
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
109

FIGURE 4

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Image Multiplier

The present invention relates to an apparatus and method for producing a number of time-resolved images from a single image, and more specifically, to an apparatus and method for plotting an electron image formed in an image converter tube by X-rays, to provide the time-resolved images. same aim

Existing time-resolving X-ray imaging systems fall into two main groups:

a) Those which rely on the pulsing of one or more of the accelerating potentials in an image converter tube so as to modulate the optical gain of the image converter tube.

b) Those which use complex deflection wave forms in an electron image converter tube to deflect an image in steps across a detector.

Both these types of devices have disadvantages:

The pulsing of an accelerating potential in an image converter tube only allows for the capture of a single image at any one time. Although one may produce more than one image by means of separate pulsed image converter tubes, each of which has a photon image incident upon its photo-cathode, each image is produced from a different viewing direction because the detectors are separated, and the resulting parallax between different images can make the interpretation of the images difficult.

Systems in which an electron image in an image converter tube is stepped around a single large detector

screen or a plurality of smaller ones are satisfactory when relatively long, of the order of 10ns, exposure times are permissible, but for exposure times of less than 1ns, it is difficult to produce and control the required deflection voltages. As a result, with such systems, image smearing can occur and time resolution is limited.

It is an object of the present invention to provide an improved method and apparatus for producing multiple images from a single electron image in an image converter tube.

According to the invention in one aspect there is provided a method of creating a plurality of images from a single image in an image converter tube, comprising the operations of producing a spatial distribution of electrons corresponding to a photon image, passing the electrons through a focusing system and creating a plurality of separate electron-deflecting fields disposed about the optic axis of the electron focusing system in the neighbourhood of the near field plane thereof so as to produce a corresponding number of electron beams representative of separate images of the original photon image.

Also according to the present invention there is provided an apparatus for producing a plurality of images from a single image in an image converter tube, comprising means for producing a spatial distribution of electrons corresponding to a photon image, an electron beam focusing system, means for establishing a plurality of separate electron-deflecting fields distributed about the optic axis of the electron-beam focusing system in the neighbourhood of the near field plane thereof thereby to produce a corresponding number of focused electron-

optical beams and a plurality of electron image converters so disposed as to intercept the electron beams and produce a corresponding number of images of the said photon image.

The original photon image may be produced by photons of any energy, but the invention is particularly suitable for use when the photon energy is in the X-ray region of the electromagnetic spectrum.

Preferably the electron-optical image converters are operated intermittently to provide a plurality of time-resolved images of the original photon image.

Preferably the electron-deflecting fields are electrostatic fields produced by a system of planar electrodes disposed symmetrically about the optic axis of the electron focusing system.

The invention will now be described and explained, by way of example, with reference to the accompanying drawings, in which,

Figure 1 is a diagrammatic representation of a known form of electron-optical imaging system. The electron-optical imaging system described is cylindrically symmetrical, but this is not a necessary requirement for the invention.

Figure 2 is a diagrammatic representation of an electron-optical imaging system similar to that of Figure 1, but embodying the present invention,

Figure 3 is a diagrammatic representation of a second embodiment of the invention, and

Figure 4 is a diagrammatic representation of a third embodiment of the invention.

Referring to Figure 1, an electron-optical imaging system 101 comprises a photo-cathode 102, a mesh accelerating electrode 103, an electrostatic focusing lens 104 consisting of a conical electrode 105 and a grounded anode electrode 106 which has a central hole 107 in it. Also included is a planar electron detector 108. The electron detector 108 may be a phosphor screen. The electron-optical imaging system 101 has an optic axis 109.

In operation, a beam 111 of photons is incident upon the photo-cathode 102 and produces a distribution of emitted electrons 112 corresponding to a photon image 113. The emitted electrons 112 are accelerated by the electrode 103, brought to a focus by the electrostatic focusing lens 104 and produce an image 114 on the detector 108 corresponding to the original photon image 113. The electrons 112 pass through a cross-over region 115 centred on the optic axis 109 of the electron-optical imaging system 101 and close to the anode electrode 106. The cross-over region 115 is analogous to the near field plane of a positive optical lens system and for the purposes of this specification is referred to as such. Similarly, the radial distribution of electrons in the cross-over region 115 is equivalent to the near field photon distribution of a conventional optical lens system. The diameter of the cross-over region 15 is determined principally by the energy distribution of the electrons 111 emitted from the photo cathode 102.

Figure 2 shows diagrammatically, an electron-optical imaging system embodying the present invention. Those components which correspond with similar components of

the electron-optical system described with reference to Figure 1 bear the same reference numerals.

Referring to Figure 2, an electron beam splitter 200 is located symmetrically with respect to the optic axis 109 of the electron-optical imaging system 201 embodying the invention, with its transverse axis 202 located in a plane 203 perpendicular to the optic axis 109 of the electron-imaging system 201 and passing through the centre of the cross-over region 115. The electron beam splitter 200 is arranged to divide the original beam of electrons 112 into two diverging electron beams 204,205, which produce separate images 206, 207 on two detectors 208, 209 respectively, instead of the single image shown in Figure 1.

The electron beam splitter 201 may be either electrostatic or electromagnetic in operation and, as shown, is cylindrically symmetric but this is not a necessary requirement of the invention.

The detectors 207, 208 are gated, that is to say, they are such that their gains can be switched rapidly in order to provide a short duration image of the electron beam incident upon each of the detectors 207, 208. Suitable devices for the detectors 207, 208 include a pulsed micro-channel plate followed by a phosphor screen, or a metal mesh at the same potential as the anode 106 followed by a phosphor screen to which a pulsed potential is applied.

Referring to Figure 3, the axially symmetrical beam splitter 200 is replaced by three equally spaced parallel plane electrodes 301, 302, 303 disposed with their longitudinal axes in a plane 304 perpendicular to the optic axis 109 of the electron-optical imaging system and

centred on the cross-over region 115. The central electrode 302 which is situated on the optic axis 109 of the electron-optical imaging system is operated at the same potential as the anode 106 and equal potentials are applied to the electrodes 301 and 303. As before, two electron beams 204, 205 and corresponding images 206 and 207 are produced on detectors 208, 209.

Figure 4 shows an extension of the arrangement shown in Figure 3. In this embodiment of the invention, a second set of three parallel electrodes 401, 402 and 403 is arranged perpendicular to the electrodes 301, 302, 303. As before, the central electrode 402 is operated at the same potential as the anode 106 and equal potentials are applied to the electrodes 401 and 403. The result is the formation of four electron beams 404, 405, 406 and 407 which are incident on detectors 408, 409, 410 and 411, where they form images 412, 413, 414 and 415, respectively. Preferably, but not necessarily, the potentials applied to the outer electrodes 301, 303 and 401, 403 of each set of electrodes are equal. Of course, in the arrangement shown in Figure 4, the two sets of electrodes cannot be co-planar but they are symmetrically disposed about a plane 418 which is centred on the cross-over region 115, as before.

If the electron-optical system is astigmatic then there are two cross-over regions, each of which is a line, usually, but not necessarily, perpendicular to each other. In this case, beam splitters can be positioned at each of the cross-over regions.

As mentioned previously, the diameter of the cross-over region is determined by the radial energy spread of the electrons emitted from the photo-cathode 102. This radial energy spread can be increased in order to make

the cross-over region larger, so facilitating the positioning of whatever beam splitting system is adopted. This can be done by making the surface of the photo-cathode 102 rough or by using a micro-channel plate as the photo-cathode. The use of a micro-channel plate as the photo-cathode will provide electron gain, making the apparatus more sensitive.

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Alternatively, an alternating radial electric field can be provided in the region of the cathode 102. The frequency of the alternating electric field should be greater than the reciprocal of the period for which each of the detectors is operational.

Claims

1. A method of creating a plurality of images from a single image in an image converter tube, comprising the operations of producing a spatial distribution of electrons corresponding to a photon image, passing the electrons through a focusing system and creating a plurality of separate deflection fields disposed about the optic axis of the electron focusing system in the neighbourhood of the near field plane thereof so as to produce a corresponding number of electron beams representative of separate images of the original photon image.

2. A method according to Claim 1 wherein electron images are produced by a plurality of electron-optical image converters which are operated in an intermittent mode to provide a plurality of time resolved images of the said photon image.

3. An apparatus for producing a plurality of images from a single image in an image converter tube, comprising means for producing a spatial distribution of electrons corresponding to a photon image, an electron beam focusing system, means for establishing a plurality of separate electron-deflecting fields distributed about the optic axis of the electron-beam focusing system in the neighbourhood of the near field plane thereof thereby to produce a corresponding number of focused electron-optical beams and a plurality of electron image converters so disposed as to intercept the electron beams and produce a corresponding number of images of the said photon image.

4. An apparatus according to Claim 3 wherein the electron-optical image converters are adapted to operate

intermittently to provide a plurality of time resolved images of the said photon image.

5. An apparatus according to Claim 3 or Claim 4 wherein the means for establishing a plurality of electron-deflecting fields comprises a plurality of parallel electrodes disposed about the optic axis of the electron focusing system with their longitudinal axes in a plane perpendicular to the said optic axis and passing through the region in which focused electrons cross the optic axis of the electron-optical focusing system.

6. An apparatus according to Claim 5 wherein there is included a second set of parallel electrodes similar to the first set of electrodes and perpendicular thereto, the second set of electrodes also having their longitudinal axes in a plane perpendicular to the optic axis of the electron focusing system.

7. An apparatus according to Claim 5 or Claims 6 wherein the electrodes are disposed symmetrically about the optic axis of the electron focusing system.

8. An apparatus according to Claim 7 wherein the or each set of electrodes has an odd number of electrodes.

9. An apparatus according to Claim 8 wherein the or each set of electrodes has three electrodes.

10. An apparatus according to Claim 9 wherein the central electrode is operated at ground potential and equal potentials are applied to the outer electrodes.

11. An apparatus according to any preceding claim wherein there is included means for increasing the cross-sectional area of the electron cross-over region.

12. An apparatus according to any preceding Claim wherein the means for producing the original distribution of electrons corresponding to the photon image comprises a photo cathode.

13. An apparatus according to Claim 12 wherein the means for increasing the cross-sectional area of the electron cross-over region comprises means for generating a radial electric field in the neighbourhood of the photo cathode.

14. An apparatus according to Claim 13 wherein the means for generating the radial electric field in the neighbourhood of the photo cathode is adapted to produce an alternating electric field the frequency of which is greater than the reciprocal of the period for which the electron detector is operational.

15. An apparatus according to any of Claims 12 to 14 wherein the photo cathode comprises a micro-channel plate.

16. An apparatus according to any preceding Claim wherein each of the electron-optical image converters comprises a micro-channel plate and a phosphor screen.

17. An apparatus according to any of Claims 1 to 15 wherein each of the electron-optical image converters comprises a metal mesh and a phosphor screen.

18. A method of creating a plurality of images from a single image in an image converter substantially as hereinbefore described and with reference to Figure 2 of the accompanying drawings.

19. An apparatus for creating a plurality of images from a single image in an image converter substantially as hereinbefore described and with reference to Figure 2 of the accompanying drawings.